CHAPTER 4

UTILIZATION OF THE FREQUENCY SPECTRUM

4.1 BACKGROUND

The rapid growth in the quantity and complexity of communication-electronics equipments and the increased international requirements for radio frequencies have placed unprecedented demands upon the radio frequency spectrum. These demands include such service applications as communications (fixed, mobile, broadcast, space); location and ranging (radar, beacons, radionavigation); identification; standard time and frequency transmissions; and industrial, medical, and other scientific uses.

The usable radio frequency spectrum, however, is a limited resource, recognized by international treaty. The Space World Administrative Radio Conference (WARC) convenes periodically to consider allocation of the spectrum. Portions of the spectrum are already critically congested, making it extremely difficult to obtain new frequencies or to increase bandwidth on presently assigned frequencies. To satisfy the demands on the spectrum in an orderly manner, a frequency management function is necessary, which incorporates solid engineering and administrative practices towards control of the spectrum supply and demand.

4.2 FREQUENCY MANAGEMENT ORGANIZATION AND RESPONSIBILITIES

Frequency management may be defined as the function whereby:

o Requirements for use of the radio frequency spectrum are presented, reviewed, and satisfied; initially, and on a continuing basis.

o Control of the use of the spectrum is exercised. The primary objective of frequency management is the satisfaction of all frequency requirements without causing degradation to communication-electronics service. Another important objective is the conservation of the radio spectrum. The organization and responsibilities of the various existing frequency management levels are described in detail in DNC-15(A), "U.S. Navy Frequency Management Handbook." Descriptions of these levels follow.

4.3 INTERNATIONAL FREQUENCY MANAGEMENT

The International Telecommunications Union (ITU) is an international body wherein the nations of the world cooperate toward improved and effective use of telecommunications and the radio frequency spectrum resource. Created in 1865, as the International Telegraph Union with 20 member nations, the ITU is now an organ of the United Nations. The major material output of the ITU results from the joint efforts of the member nations, usually in the form of Radio Regulations which have treaty status and thus, upon adoption by a country, become the law of the land. ITU headquarters are in Geneva, Switzerland, where a permanent secretariat is supported by member nations.

The ITU establishes and promulgates the international allocation of, and regulations for the use of, the radio frequency spectrum. It also promotes the development of technical facilities and establishes doctrine for international telecommunications, including the aforementioned Radio Regulations. The ITU Secretariat serves as a focal point for disseminating to all member nations such information as stations, call signs, radio service

schedules, and recommended technical standards and tolerances. An international monitoring effort is also maintained under ITU auspices for the purpose of determining spectrum occupancy.

There are several international technical bodies within the ITU. They strengthen and support the parent organization and contribute directly to improved telecommunications by such means as technical papers and recommended standards.

4.3.1 Basic Rules for Assignment and Use of Frequencies

a. ITU member nations have agreed that, in assigning frequencies to stations capable of causing harmful interference to the services rendered by stations of another nation, such assignments must be made in accordance with the Table of Frequency Allocations and other provisions of the Radio Regulations.

b. Any new or revised assignment shall be made in such a way as to avoid causing harmful interference to services rendered by assignments made in accordance with the Table of Frequency Allocations and recorded in the Master International Frequency Register.

c. The frequency assigned to a station of a given service shall be separated from the limits of the band allocated to this service in such a way that, taking into account the bandwidth assigned, no harmful interference is caused to services to which frequency bands immediately adjoining are allocated.

d. Where a band of frequencies is allocated to different radio services in adjacent geographic regions, the basic principle is the equality of right to operate. Accordingly, the stations of each service in one region or sub-region must operate so as not to cause harmful interference to services in the other regions or sub-regions.

4.4 NATIONAL FREQUENCY MANAGEMENT

The basis for U.S. National Frequency Management is derived principally from the Communications Act of 1934, as amended. This Act provides for a bilateral arrangement; the Federal Communications Commission (FCC) is responsible to the Congress for the regulation of United States non-government activities; the President is responsible for the operations of federal government agencies consisting of the following:

o The President, by Executive Order, has delegated the task and authority for assignment and control of radio frequency resources used by government agencies to the Office of Telecommunications Policy (OTP) under the Executive Office of the President. The OTP is responsible for formulating policies and standards pertaining to the operation of telecommunications systems by government activities, subject to the authority and control of the President.

o The Interdepartment Radio Advisory Committee (IRAC), established in 1922, and composed of frequency management representatives of principal government agencies engaged in use of the frequency spectrum, serves in advisory capacity to the OTP. The Departments of the Army, Air Force, and Navy each has representation on the IRAC.

o Functions of the Interdepartment Radio Advisory Committee, acting for the OTP, are to approve, in collaboration with the FCC, the allocation of frequency bands to radio services in the United States and Possessions (US&P) within the provisions of the international allocation table, to authorize the assignment of frequencies to government radio stations, to assist and advise appropriate national authorities on related technical problems, and to serve as an advisory body to the Department of State in the formation of U.S. positions for international conferences.

o The actual assignment authority for the radio frequency use by the U.S. government agencies is vested in the Frequency Assignment Subcommittee (FAS) of the IRAC, which is composed of the representatives of the following government agencies with liaison representation from the FCC:

Department of Agriculture
Department of the Air Force
Department of the Army
Department of Commerce
Federal Aviation Agency
Department of Interior
Department of Justice
National Aeronautics and Space Administration
Department of the Navy
Department of Transportation
Department of Treasury
United States Postal Service
United States Information Agency
Veterans Administration
Atomic Energy Commission
National Communications System

o Among government agencies not participating in the FAS, but served by it are: Department of Health, Education, and Welfare; Tennessee Valley Authority; and the Federal Reserve System.

o Prior to use of any radio frequency within the US&P, except certain military low power tactical and training operations, and ECM operations which do not fall within a restricted frequency band, U.S. government agencies are required to obtain authorization in the FAS for the specific frequency and parameters of use. The procedure for coordination and use of certain non-government allocated frequencies for military tactical and training purposes is set forth in the OPNAVINST 2410.19 series, and JANAP 195.

o Listings of all assignments approved for government agencies by the FAS are contained in the volumes of the "Frequency Assignments to Government Radio Stations," commonly known as the "IRAC Station List." The list for which revisions are regularly printed, is promulgated by the IRAC on behalf of the OTP. The IRAC also publishes the U.S. National Table of Frequency Allocations. This table amplifies the ITU allocations in the form of subdivisions of basic radio services plus delineation as to whether government and/or non-government operations are authorized in each allocation.

4.4.1 Department of Defense Frequency Management

The Department of Defense, as an entity under the Secretary of Defense (as well as the three military departments individually) is an integral component of the U.S. National Frequency Spectrum Management structure.

The prime focal points, however, are the principals of the communications-electronics staffs of the military departments who respond through the Joint Staff or intradepartmental chain according to the joint or intradepartmental nature of a matter under consideration. The flow of authority on frequency matters may be multilateral through the Secretary of Defense. Coordination on a single Navy frequency problem may go through both chains. Policy and assignment of responsibilities within the Department of Defense are established by DOD Directive 4650.1 series,"Management and Use of the Radio Frequency Spectrum."

Levels of Department of Defense frequency management responsibility are briefly described in the remainder of this chapter.

a. Military Communications-Electronics Board (MCEB)

(1) The mission of the MCEB is to:

o Achieve coordination on military communications-electronics matters among DOD components, by the DOD and other governmental departments and agencies, and between DOD and representative of foreign nations.

o Provide DOD guidance and direction in those functional areas of military communications-electronics for which the MCEB is assigned responsibility.

o Furnish advice and assistance, as requested, on military communications-electronics matters to the Secretary of Defense, the Joint Chiefs of Staff, the military departments and other DOD components.

(2) The MCEB is composed of:

o The Director, Defense Communications Agency (DCA), chairman

o The Chief, Communications-Electronics, U.S. Army

o The Director, Naval Communications (COMNAVCOMM)

o The Director of Command, Control and Communications, U.S. Air Force

o The Chief, Communications-Electronics, U.S. Marine Corps

o The Director for Communications-Electronics (J6), Joint Staff

o A representative of the Director, National Security Agency

b. Joint Frequency Panel (JFP). The Joint Frequency Panel is responsible to the Military Communications-Electronics Board in the accomplishment of its mission in the areas of radio propagation and frequency allocation, coordination and assignment. The JFP consists of a minimum of one member and an alternate from each service or Agency within the composition of the MCEB who has an interest in the activities of the Panel plus one representative and an alternate from the U.S. Coast Guard. The present membership consists of Army, Navy, Air Force, Joint Staff (J6), USMC, Coast Guard, DCA, and NSA.

The mission of the JFP is to:

(1) Review, develop, and coordinate studies.

(2) Report DOD positions and recommendations for the MCEB on frequency management and engineering, radio wave propagation, and electromagnetic compatibility (EMC).

(3) Implement for MCEB the provisions of DOD Directive 4650.1, "Management and Use of the Radio Frequency Spectrum."

(4) Coordinate frequencies to meet joint, national, and allied requirements.

(5) Coordinate and assign frequencies to meet U.S. military requirements (other than those of an individual service nature).

(6) Coordinate and assign unified command frequencies.

c. Unified and Specified Commands. The commanders, under the Joint Chiefs of Staff have overall management and control responsibility of all U.S. military use of radio frequencies within their zones of operations; this has significant impact upon the Navy frequency planning form for worldwide fleet and shore establishment operations.

The JFP coordinates with a Commander in Chief (CINC) all JFP frequency assignments made to that CINC's area of jurisdiction. Under certain conditions (U.S. Supp. 1A, ACP*190), the unified commander can assign frequencies for low powered local operations (under 500 watts) without reference to the JFP. All assignments (including those under 500 watts) within U.S. possessions must have IRAC approval. The unified commander submits to the JFP all frequency requirements for low power operation for which no authority exists in the IRAC publication.

d. Defense Communications Agency (DCA). The DCA was established in 1961 with the mission of ensuring that the Defense Communications System (DCS) would be so established, improved, and operated as to meet the long-haul, point-to-point, requirements of the Department of Defense and other associated government agencies as directed. The DCA is a management agency with no operational functions as such. The system with which they are concerned is basically the network of long-haul, point-to-point circuits operated by Army, Navy and Air Force communications organizations. Certain responsibilities are also assigned to DCA in connection with satellite communications. The Director of the DCA is selected by the Secretary of Defense.

The agency consists of a headquarters staff in Washington, D.C. and such other worldwide facilities as the Director, DCA feels justified for accomplishing the assigned mission. Staffing is effected from military personnel of the different departments, in accordance with directed demands upon the departments to support the DCS. The Director, DCA, is the Chairman of the MCEB. Detailed amplification of DCS definitions for the purpose of their mission is contained in DOD Directive 5205 series.

e. Area Frequency Coordinators (AFC). An inter-service area frequency coordination system was established by the JFP to ensure minimum interference to the C-E systems employed and tested on the national ranges. Specified areas of geographical cognizance are given in DNC-15(A). Frequencies intended for use in these areas are coordinated with the applicable AFC before assignment. The JFP has assigned the following responsibilities to the AFC (nothing in these functions is intended to usurp services' or commanders' prerogatives or responsibilities in frequency management):

o AFC s review and evaluate assignment requests proposed for use within their area. The review and evaluation establishes the compatibility of proposed frequencies with test range operations and other activities in the area. Requests in the Continental United States are forwarded to the departmental headquarters of the requesting military activity with supporting technical comment.

o AFC s assist, when requested, in the elimination of real-time harmful interference to in-being ranges and test site operations. In performing this function, the AFC s are authorized to request temporary radio silence, on a frequency or band of frequencies, of the interfering activity for the period of time necessary to complete operations in progress.

o AFC s may arrange, by mutual agreement among military activities within their geographical area, for time sharing and technical adjustments (emission, power output, etc.) on frequency assignments, as required, to minimize harmful interference.

* Allied Communication Publication

o AFC s maintain records of frequencies which have been coordinated and assigned for use in their areas. These records include frequencies assigned to military activities, military contractors, and those government and non-government assignments being shared with test range frequency assignments. Records of AFC s are made available to military activities for frequency planning.

4.4.2 U.S. Navy Frequency Management

Allocation for Navy Electronics Equipment. An office under the Chief of Naval Operations (CNO) has the responsibility for the Department of the Navy to secure joint approval of the frequency allocation provision for all Navy electronic equipments or systems purposely designed to emit or receive electromagnetic energy.

Such provision is effected prior to the development, procurement, or adoption of such equipments or systems. Unlike frequency assignments, authority to approve frequency allocation is always at the level of the office of CNO. Furthermore, CNO does not respond to an originating Navy Command or other development activity's request for allocation without having first secured joint approval, be it an experimental, developmental, or operational frequency allocation.

a. The Commander, Naval Communications (COMNAVCOMM) obtains authority for the use of radio frequencies within US&P in the following instances:

o For USN/USMC Communication-Electronics (C-E) operations which are physically located on board USN/USMC installations.

o For USN/USMC C-E operations on installations of other military departments.

o For C-E operations required to support jointly operated (e.g. USN/FAA) facilities on board USN/USMC installations.

o For the ECM type equipments which fall within restricted bands, OPNAVINST 3430.9 series pertains.

b. COMNAVCOMM does not normally obtain authority for the following type of operations:

o Facilities of military and nonmilitary agency tenant activities aboard a USN/USMC shore based installation not jointly operated with those agencies.

o Temporary operations by elements of other agencies on board USN/USMC shore based installations where those agencies have adequate frequency authorization.

The importance of the allocation provision process in the sequence of furnishing systems to the Fleet is supported by the policy of the Chief of Naval Material (CNM) which serves as a checkpoint in preventing expenditures for electronic equipments which lack required radio frequency allocation. This guidance to potential Navy procurement activities is set forth in NAVMAT Instruction 10550.11 series.

In order to be better prepared for consideration of spectrum allocation policy and engineering matters, the cognizant office of CNO reviews operation requirements papers generated within the Navy; continues such reviews through the development of Specific Operational Requirements (SOR s), Technical Development Plans (TDP s), which inform planning and material offices of any adverse elements noted; and makes such recommendations as are deemed appropriate from a frequency standpoint. Difficult or controversial items are studied and resolved by the Frequency Allocation Advisory Board (FAAB), the principal frequency coordinating body within the Navy.

In order to evaluate effectively the compatibility aspects of electronic equipments under conditions of anticipated operational employment as well as to conform to the national structure of frequency management, an orderly procedure for the processing of frequency allocation applications is necessary. Each military department is responsible for processing information to the JFP, a component of the MCEB, and for enforcement of resultant decisions. The procedure is promulgated within the Navy Department in OPNAVINST 2410.11 series, NAVMATINST 10550.11 series, and NAVELEXINST 2400.1. In those instances where research and development efforts are conducted under contract by private industry, it is the responsibility of the cognizant Navy SYSCOM to maintain sufficiently detailed surveillance of such activities to ensure that applications for experimental or developmental equipments are treated in advance of those submitted for production equipment programmed for operational use.

Applications are submitted to CNO in accordance with the instructions noted previously. Applications for frequency allocation are studied by CNO in the light of existing Joint Military electronic equipments, established design objectives, and the probable impact from and upon new equipment under development. The effective editions of JANAP 141 (U.S. Joint Military Radio Frequency Allocation Plan) and the Frequency Allocation List, U.S. Military Electronic Equipment are pertinent. Appropriate equipments are also considered for their impact on the combined environment by a Canadian-United Kingdom-United States working group of the Combined Frequency Panel.

Frequency allocation provisions are prescribed for each equipment on the assumption that production for operational (or for research and testing) use will materialize. CNO provides the Chief of Naval Material with copies of all completed frequency allocation actions, whether approved or disapproved, including conditions and modificaton recommendations.

4.4.3 Frequency Assignments

Even though a frequency band may be allocated to a service by international and national agreements, and an allocation has been approved for a specific transmitter on a Navy installation, specific authority in the form of an ASSIGNMENT is a prerequisite for use of the RF spectrum.

When it becomes necessary for a Navy command to set up a radio frequency transmission (other than in connection with Fleet Tactical Plans) at a specific location or for a purpose not already authorized, or in expansion of the frequency provisions of an already authorized operation, specific authority must be obtained from the Chief of Naval Operations or the Unified Commander, as appropriate. In turn, intramilitary, national, and international coordination will be effected, as necessary.

The first element of this process is validation of the requirements. Various steps in clearance coordination follow, culminating in the assignment. Frequency management action is concluded with entry into pertinent records. Monitoring of assignments to ensure continued need and usage is a never ending, follow up action.

COMNAVCOMM assigns all radio frequencies for use by USN/USMC activities within the US&P. In certain frequency bands COMNAVCOMM has assigned radio frequencies to Fleet Commanders in Chief and Naval District Commandants for further assignments. These assignments are covered in the various chapters of JANAP 195.

o The Fleet Commanders in Chief and Naval District Commandants are authorized to further assign specific operating frequencies, as appropriate, in those cases where the CNO has assigned frequency bands or complements of frequencies to the Fleet Commanders in Chief or Naval District Commandants.

o Fleet Commanders in Chief and Naval District Commandants maintain a current record of specific assigned frequencies in accordance with the previous paragraph.

o Naval District Commandants report to COMNAVCOMM all permanent frequency assignments made by the Commandant under broad COMNAVCOMM authority (less tactical and training assignments made pursuant to OPNAVINST 2410.19) in the bands 30-42 MHz, 138.0-150.8 MHz, 225-400 MHz. This information is required to determine and maintain records of U.S. Navy utilization of the radio frequency spectrum and is used for planning purposes at the national level.

In cases where COMNAVCOMM has assigned frequencies to the Fleet Commanders in Chief or Naval District Commandants for use by activities or installations under their cognizance, temporary variations in the assigned utilization of such frequencies may be authorized by the Fleet Commanders in Chief or Naval District Commandants as long as the remainder of COMNAVCOMM assignment parameters are observed.

Within the area of responsibility of a Unified Commander, frequency assignments are made by the Unified Commander in coordination with the Joint Frequency Panel of the USMCEB on behalf of the Joint Chiefs of Staff, as appropriate.

No radio frequency below 30 MHz is assigned to point-to-point (fixed circuits located within CONUS), except in one or more of the following instances:

o When security factors dictate paralleling wire circuits with radio circuits in essential communication channels of a command network (standby stations).

o When the radio circuit is for the domestic haul of overseas traffic, and is a relay segment of that overall system.

o When the use of other means of communication is impractical. Neither budget, personnel, nor convenience should be considered factors to justify satisfying a domestic point-to-point requirement for use of radio.

Active ECM Operations. Frequency authorizations for active Electronic Countermeasures (ECM) operations in the United States and Canada are established for U.S. Military units on a standing basis for certain bands, to be satisfied for each individual operation through local coordination. Authority, restrictions by band, and detailed coordination procedures are contained in a Joint Directive promulgated within the Navy Department under OPNAVINST 3430.9 series.

Operation of Naval Radar Equipment. Assignments for operation of Navy and Marine Corps radars are for the most part less specific as to center frequency in CNO and/or JFP authorization than in the case of other types of equipment. For this reason, greater attention must be given to operational directives and local coordination by operating force and shore based commanders. Assignments are authorized on a band or tuning limits basis to Fleet Commanders and District Commandants. Adjustment of tunable equipments for operation are then as set forth in JANAP 195. Within CONUS, frequency plans for fixed installations, as well as mobile units within the jurisdictional area, are the responsibility of the Naval District Commandant. Policy and procedures governing employment of IFF in conjunction with radar is set forth in JANAP 195 and OPNAVINST 2380.1 series. When a location is encompassed by the jurisdiction of a Test Range Area Frequency Coordinator, coordination with such office is also necessary. Operations in a theater under the control of a U.S. Unified or Specified Commander are subject to such additional instructions as may be issued to minimize interference in the theater, especially as regards operations within interference range of foreign countries where radar or other allocations may differ from U.S. allocations or uses.

4.4.4 Requests for Frequencies

Prior to the operation of any device intentionally radiating electromagnetic waves, a radio frequency authorization is obtained from competent authority.

Requests for the assignment of radio frequencies are normally submitted as follows:

o Requests for frequencies by shore activities for use within CONUS are submitted to the COMNAVCOMM via the Naval District Commandant and additionally, in the case of Naval tenant activities, via the base or installation commanders concerned.

o Requests for frequencies in the area of responsibility of a Unified/Specified Commander are submitted via the chain of command to the Unified/Specified Commander.

o Fleet units based ashore requiring radio frequencies for use at shore installations request frequencies from the cognizant Naval District Commandant.

o Requests for frequencies to be used by Naval Communications Stations are submitted to the COMNAVCOMM via the appropriate Fleet Commander in Chief.

Requests for frequencies to meet routine, foreseeable requirements should be received by the COMNAVCOMM in the format prescribed in Allied Communication Publication (ACP) 190 U.S. Supplement 1, "Basic Armed Forces (U.S.) Frequency Planning," at least sixty days prior to commencement of the requirement.

Requests for frequencies to be used within the area of cognizance of an Area Frequency Coordinator (AFC) or Sub-Area Frequency Coordinator (Sub-AFC), normally should receive comments from the appropriate AFC or Sub-AFC prior to receipt of the request by COMNAVCOMM or unified commander.

When a requirement exists for a shore based activity, within CONUS, to operate in local civil police, fire, or emergency nets, the request should list the specific frequency to be employed and should also include a letter of concurrence from the local civil agency involved.

When a requirement exists for a frequency assignment for a station located on any land or reservation under the jurisdiction of the Forest Service, Department of Agriculture or the Bureau of Land Management, Department of the Interior, the date of notification for permission to make the installation on the subject land or reservation, and the land office from which the notification was received, should be forwarded to COMNAVCOMM with the request for a frequency assignment.

USN/USMC activities with requirements for the use of 27.575 MHz or 27.585 MHz, in accordance with the provisions of JANAP 195, should submit requests for authorization to the appropriate Naval District Commandant.

Requests for renewal of frequency assignments made on a temporary basis should also be forwarded to reach COMNAVCOMM at least 60 days prior to the expiration of the temporary assignment.

4.4.5 Frequency Usage Program

A key part of Navy frequency management is the program of submission and employment of radio frequency usage reports. Details of action required by field activities in submission of reports are promulgated in the OPNAVINST 2400.7 series.

4.5 FREQUENCY SELECTION AND ENGINEERING

4.5.1 Planning Factors

The saturation of the limited radio frequency spectrum has been described. Maximum economy in the utilization of the spectrum is therefore essential in order that vital operations will not be degraded by inefficient distribution of this resource. The first duty of a requirements planner is to exhaust all possible combinations of power/emission and sharing of existing frequency assignments in meeting new requirements. Requests for routine, foreseeable frequency requirements must be submitted with sufficient lead time (60 days desired) so as to provide adequately for coordination at the Washington level as well as with major Area Frequency Coordinators (AFC's). Requests should normally include, in addition to specific frequencies desired and frequency limits if applicable, the following:

o Type of service

o Points or areas of intended use

o Maximum power and desired emissions

o Equipment nomenclature

o Hours of operation

o Operations command.

a. This procedure is enumerated in JANAP 195. It is essential that initial requests be detailed adequately, clearly justified, and indicative of the results of any advance coordination effected by the originator. The latter might entail an FCC Field Engineer in Charge, FAA Regional Office, Military Test Range Area Frequency Coordinator (AFC), District Commandant Frequency Coordinator, etc. Advance local coordination, particularly at commands based overseas, may also include that informally effected with a foreign military liaison officer. The details necessary to decision making will vary with each individual situation. The originator should consider all echelons at which the matter will be treated in adjudging items of the standard format and provide extra amplifying facts as necessary to enhance the coordination process.

b. Communications circuit frequency assignment requests may be for augmentation of existing circuits or entirely new circuit paths, or may be for temporary periods for experimental work or tactical and training exercises. Advance direct coordination and subsequent "Viz" or "Copy to" inclusion in formal requests is dependent upon the chain of command plus other commands that are known to have frequency control responsibility or established radio services entailing potential mutual interference. The originator and each command commenting upon a proposal is responsible for adjudging that, if approved, the additional occupancy of the RF spectrum will not create harmful interference to established radio services. Additionally, justification of the requirement should be considered at each step in the chain of command processing.

c. Other significant planning factors

(1) Spectrum Limitation. Spectrum limitation is greatest in the HF portion (3-30 MHz) of the spectrum, especially during the low portion of the solar sunspot cycle. Practically all of the frequencies for point-to-point Defense Communications System circuits and for long-range tactical communications must be satisfied herein. To some extent, frequencies (1.7-3 MHz) in the MF band also serve such circuits depending upon terminal locations, time of day, and local noise variations. The headquarters frequency manager has large numbers of new circuit frequency requirements to satisfy, many with bandwidth requirements up to 12 kHz. New circuit requirements originate with the creation of new countries as well as with almost every reorganization or establishment of military commands and international economic or military treaty bodies. It has been estimated that the demand upon the HF band has increased by 300 percent in the past 20 years. Multiple assignments and extensive sharing are thus inevitable. Users are being placed under increasing national and international pressure to present justification for retaining all existing assignments in the HF band.

(2) Time and Geographic Sharing. Of the two modes of frequency sharing, time, and geographic, geographic sharing is the only one practical for many frequency assignments due to the around-the-clock nature of many operations. This is true in all portions of the spectrum from LF beacons to SHF radars, particularly in the case of military operations which are either operational 24 hours a day or must be maintained in a constant state of readiness. Problematical in geographic sharing, however, is the variable nature of radio wave propagation conditions, especially as regards the ionosphere. These variations may result in periodic harmful interference among users of the same or adjacent frequencies. Planned geographic sharing is more complex in the case of mobile operations. Mobile service assignments may be "pooled" in such a way as to ensure increased sharing, regardless of deployment. This concept is reflected extensively in the latest edition of JANAP 195. "Hubbing", the use of assigned complements for a multiplicity of point-to-point circuits emanating from a given source, is

also employed extensively. Ship-to-shore tactical assignments are further amplified in OPNAVINST 2410.23. While there has long been an interference problem in the HF band due to propagation variations, expansion of high powered LF and VLF systems, increased use of high powered radar and radio control systems (UHF and above), and the advent of space and scatter systems in the VHF and UHF bands increase the probability that these systems will also cause and/or receive harmful interference.

(3) Assignment Coordination Delay. The time delay in effecting coordination of frequency assignments is inevitable and creates a real problem of Navy standards of responsiveness. Rapid wartime communications electronics expansion cannot be restricted by the same delays. The importance of frequency resources in contingency planning is thus a paramount consideration. The time between receipt of a valid frequency requirement in Navy headquarters until assignment of a suitable frequency may vary from minutes in less congested portions of the spectrum to several months in bands of great demand. The amount of time required for negotiations will depend upon several factors, e.g., does the Navy have authority to use the desired frequency with similar power and emission in the desired terminal areas, is the intended service allocated on a primary basis in the desired frequency band, and particularly, does the area of intended use involve a foreign sovereignty with whom coordination must be effected?

Variations among sovereign administrations as to frequency coordination procedures, as well as the political atmosphere at any given time, may serve to further compound the problem.

(4) Obstacles to Reallocation. In the best interest of overall spectrum efficiency, many services in saturated frequency bands might be shifted to less saturated bands, within the technical parameters of the operations concerned. This step has been deemed necessary and so ordered in several instances (certain radar and telemetry bands are recent examples). Opposition to major reassignment or reallocation actions is quite strong many times, and justifiably so. A serious consideration involves plant investment. Other primary factors are the time and budgetary support inherent in design, development, and installation of hardware necessary for a service to function in a significantly different portion of the RF spectrum. The prospect of having to negotiate new complements of frequencies for an established service may also be a deterrent to considering major change. The lengthy time required for negotiation in addition to the loss of latent priority of older frequency assignment registrations or agreements are further considerations. The severity of this problem may be evaluated by the extent of involvement in the following areas:

- o Change of Table of Allocation of bands to radio services

  International
  National
  Intra-Military

- o Operation of many units of similar equipment; i.e., many required in case of communications.

- o Proposed re-accommodation or new service conflicts with expanding authorized service in one or more regions of the world.

(5) Communications. Frequency spectrum congestion and expanding communications requirements within the foreseeable future dictate the need for optimizing tuning resolution capability and maximum practicable frequency stability in radio communications equipment. Navy communications equipment currently being developed for operation in the 14 kHz to 2 MHz range, the 2 to 30 MHz range and the 225-400 MHz range shall have the capability to tune in accordance with the latest standards and instructions.

(6) Other Electronics. Certain OPNAV Instructions have been promulgated which require all electronic equipment design agencies to consider the elimination or reduction of interference in the design of equipment under their cognizance. In an effort to provide interference free operation as well as efficient utilization of frequency bands allocated for radar use, minimum radar engineering design requirements have been developed and set forth in MIL-STD-469.

d. In order to select frequencies for new equipment with the object of avoiding interference, the planner should have information on other users of the spectrum. The following publications may be consulted to obtain the required information:

- o International Frequency List (IFL): Seven periodically updated volumes.
- o IRAC Station List: Six periodically updated volumes.
- o FCC Non-Government Station List: Nine volumes.
- o U.S. Military Joint Radio Frequency Allocation Plan, JANAP 141.
- o National and International Allocation Tables.
- o Navy Master Copy, JANAP 195.
- o Navy Master Frequency Clearance and Authorization Record (updated daily, complete master index).
- o Quarterly Usage Report IBM Extracts.
- o Frequency Coordination Card Files.
- o Files of IRAC (FAS) Dockets.
- o Interference Report Case Files.
- o Frequency Lists of Unified Commanders and Joint Missile Test Ranges (PACOM FAU, EUCOM FAU, PACMISRAN, etc.).

4.5.2 Technical Factors

Frequency engineering can be thought of as the technical component of spectrum management. It may be defined as the process of selecting specific frequencies or bands of frequencies to be used for the performance of specific communications electronics services or functions. The selection of frequencies within the requirements of a particular system or equipment is primarily based on the goal of interference-free operation of all systems in the electromagnetic environment.

Other important considerations are conservation of the electromagnetic spectrum and future frequency requirements of the system.

a. Class of Service Considerations. The selection of a frequency band for a specific circuit is generally determined by the transmission properties of the band, the availability of frequencies within the band, the type of equipment available, and other factors. Selection criteria for the various bands have been documented in DNC-14 series, NAVELEX 0101,103, and other service publications, engineering texts, and papers. A brief discussion of the various bands follows.

b. Propagation Characteristics. Table 4-1 depicts the propagation characteristics of the various portions of the RF spectrum. Essentially, both sky waves and ground waves are generated at any frequency from almost any antenna. However, one or the other may be so minute as to be negligible. Along the earth's surface, the maximum distance a ground wave is effective is inversely proportional to the wave frequency. Also, ground waves undergo deviation from normal straight line travel by lower atmosphere refraction, bending of waves through a

Table 4-1. Propagation Characteristics of the RF Spectrum

BAND		PROPAGATION CHARACTERISTICS	TYPICAL USES
Below 3 kHz	ELF	Same as LF	Very long distance point-to-point (greater than 1000 nautical miles)
3-30 kHz	VLF	Same as LF, except attenuation equally low, day or night; reliable	Very long distance point-to-point. Fleet broadcast communications
30-300 kHz	LF	Primarily ground waves low attenuation, reliable, daytime absorption of sky waves greater than at night	Long and medium range (50 to 1000 nautical miles, point-to-point communication, marine, Navaids
300-3000 kHz	MF	Ground waves but some ionospheric sky waves, attenuation of sky waves low at night and high in daytime. Subject to ground-sky wave interference for distances less than 500 nautical miles.	Broadcasting, marine communications, Navaids, harbor telephone, medium and short range
3-30 MHz	HF	Transmission over great distances, depending on ionosphere. Varies greatly with time of day, season, frequency and portion of solar sunspot activity cycle. Subject to ground-sky wave interference at short distances	Moderate and long distance communications of all types
30-300 MHz	VHF	Sporadic ionospheric effects occur during high portion solar cycle	Short distance, line-of-sight communication, television, FM broadcasting, Navaids, radar, over-horizon "scatter" communications, aero-Navaids
300-3000 MHz	UHF	Same as EHF	Short-distance communication, radar television, aero-Navaids, point-to-point relays, over-horizon "scatter"
3-30 GHz	SHF	Same as EHF	Short-distance communication, radar, point-to-point relay systems, Navaids, satellite relays
30 GHz	EHF	Substantially straight line propagation analogous to that of light waves. Unaffected by ionosphere	Radar, radio-relay Navaids

particular propagation medium, diffraction (phenomena of waves bending around objects) and propagation along the curved surface of the earth because of the earth's conductivity, property of matter which enhances propagation of electromagnetic waves; all of which extend the distance of propagation beyond the line-of-sight distance. Sky waves undergo travel deviation in the atmosphere to varying degrees as a result of refraction, scattering, and absorption.

The ionosphere, a region of the upper atmosphere approximately 40-250 miles above the earth's surface, is formed primarily by the ionizing effects of the sun's ultraviolet light. It is possible to predict to some degree, the intensity of the ultraviolet light radiated by the sun, hence, the degree of ionization and the behavior of radio waves which use the ionosphere as a propagational media. Cosmic rays, X-rays, meteors, and actual particle radiation from the sun also have an effect on the ionization of portions of the ionosphere. At times this ionization is sufficiently great to cause disruption to long distance radio communications.

For a given operation, frequencies calculated as capable of propagating along the particular path should be selected from an authorized resource such as JANAP 195. The high frequencies required for long-range communications and data circuits will vary according to time of day, season and portion of the solar activity cycle; therefore, such circuits inevitably will have several frequencies assigned as a complement to provide for 24 hour operations.

There is significant use of both manual and computerized ionospheric predictions, long and short term, in the design, planning for, and operation of radio communications systems. Long-range predictions are published by countries such as Great Britain, Canada, Japan, and the United States. The real-time requirements of traffic control centers dictate that some way be found for updating the long-term predictions used in assigning frequency complements. Related projects and planned advanced naval communications complexes are oriented toward meeting this need.

c. Phenomena Of Naturally Caused Interference. Precipitation static and atmospheric, solar, and cosmic emissions all have an adverse effect upon the signal level required to receive intelligence. Atmospheric effects are predominant for communications where frequencies below 20 MHz are involved. For frequencies above 20 MHz, receiver set inherent noise and cosmic emissions become predominant, and solar effects are noticeable. Cosmic emissions that penetrate the atmosphere generally interfere only in the 20-100 MHz range in quiet (low set noise) receivers at quiet locations. Solar emissions that penetrate the atmosphere are noticeable only on sharply beamed antennas during periods in the earth's rotation when such antennas are on particular bearings relative to the sun and affect all frequencies above UHF. Precipitation static and atmospheric phenomena result from electrostatic storm disturbances (thunderstorms) in the earth's atmosphere causing interference in bands utilizing ground and sky-wave propagation. Atmospheric effects are transmitted long distances via the ionosphere, losing intensity through attenuation. The effects originate primarily in the tropical zones and cause relatively little interference in the polar zones.

d. General Communications Service Characteristics

(1) Fixed Service. Frequency requirements for fixed services are related directly to distance along great circle paths between fixed earth terminal points. Long distances dictate the use of high frequencies where propagation is predominantly by sky wave (ionospheric layer reflection). Intermediate distances of 15-1000 nautical miles dictate the use of MF and LF where there are both sky and ground-wave propagation modes. Upper UHF and mid SHF bands previously limited generally to line-of-sight are now applicable to certain long haul applications through the development of microwave relay systems. Fixed paths are conducive to planned geographic sharing within the variations of natural radio wave propagation phenomena.

(2) Mobile Service. Frequency requirements for mobile services are related to a wide range of distances and also to the nature of the Mobile Service (Maritime, Land, Aeronautical). Long and medium distances dictate use of MF and HF. UHF above 60 MHz is best for land or sea short distance communications, while VHF/UHF is used for aeronautical short distance communications. Except for broad parameters, the mobile services are not particularly conducive to planned geographic sharing, especially when potential long distance requirements dictate the use of HF, which would increase the probability of harmful interference to other services.

(3) Broadcast Service. Frequency requirements are related primarily to the maximum effective coverage desired. This service is intended by definition, for the reception generally by the public throughout areas specified in the authorizations (licenses) for each station to which a frequency is assigned. Internationally, radio and television broadcast service stations use frequencies ranging from 150 kHz to over 800 MHz. The Navy's Fleet Broadcasts have corresponding requirements to serve all Fleet units within given Fleet Broadcast Areas, although recent state of the art and tactical developments have introduced improved VLF applications. Predicted coverage of broadcast service transmissions supports both time and geographic sharing of frequencies to a limited extent. Standard Time and Frequency Broadcast assignments of specific frequencies follow the same selection criteria; therefore, these assignments are widely promulgated.

(4) Radiolocation Service. Applications of radiolocation services are basically line-of-sight in nature. Of primary concern to the Navy frequency manager are the many radar, radio-command-control (drone) and similar requirements that demand broadband portions of the VHF, UHF, and SHF bands. To a lesser extent, some portions of the HF band are utilized for distance measuring and surveying equipments, such as LORAC and RAYDIST.

(5) Radionavigation Service. Two distinct services, Maritime Radionavigation and Aeronautical Radionavigation, are identified under this service category. These systems (Radio Direction Finding (DF), FM and Radar Altimeters, Navigational Radar, Homing Beacons, TACAN, LORAN, OMEGA, etc.) employ a variety of transmission characteristics and distance capabilities and require frequency support ranging from VLF to SHF. Band allocations have been established, due to safety-to-life considerations. on a national and international basis and may be appropriate for sharing with other services with the condition that harmful interference is not caused to the Radionavigation Service.

For Maritime Radionavigation, several LF and MF bands serve the beacon and position fixing requirements.

For Aeronautical Radionavigation, requirements are as follows:

o Homing Beacons:

Long range at the lower end of MF band (about 300 kHz adjoining Maritime Radionavigation beacons).

Short range at mid-VHF

o TACAN: 960-1215 MHz.

o Altimeters: Near 1700 and 4300 MHz.

o Radar: For air traffic control, ground control approach, tracking, etc., several portions of the spectrum in the upper end of the UHF and in the SHF band.

(6) Telemetry And Space Service. Telemetry is usually further identified with another service designation with which the operation is associated, such as Meteorological, Space, Oceanographic, Aeronautical, etc. Nearly all the requirements are line-of-sight and are met in several ranges of frequencies in the SHF band. Distances involved in some ocean buoy to shore transmission require high frequencies. Special frequency allocation provisions in the crowded HF communications bands are under consideration at the international level. Reflected in the International Table of Frequency Allocations, are expanded provisions for space research and communications operations.

4.5.3 Considerations for Frequency Selection for EMC

The selection of frequencies to provide the most reliable and least interfering transmission for those locations having multiple transmitter-receiver configurations requires consideration of many factors. Numerous methods of selecting frequencies for specific service type have been devised, based on various interference criteria, e.g., interference margins, mutual interference matrices, etc. These will be discussed in greater detail in subsequent chapters of this document. Because of the complexities of multiple collocated equipment, many of these methods have been conceived for use with automated, data processing equipment. Also, because of the random nature of both the propagation medium (particularly for HF service) and the equipment coupling mechanisms, the use of statistical techniques has become common. Paragraph 1.5 describes the services provided by the DOD Electromagnetic Compatibility Analysis Center in the area of frequency assignment and selection. Important considerations are listed as follows:

a. The determination of susceptibility to emissions of all systems in the electromagnetic environment.

b. The determination of transmitter-receiver frequency separation requirements.

c. The determination of geographic space separation requirements for combinations of systems-equipments (interference predictions).

d. The determination of frequency groupings or channelizations to satisfy the separation requirements and to minimize intermodulation products and spurious outputs and responses.

e. A guard band,several RF channels wide,may be established between transmitting and receiving frequencies. If the radio sets used have numerous spurious outputs and responses, a simple guard band may be insufficient.

f. Adjacent channels should not be used by receivers in the same installation. If the wanted signals for two receivers are of widely different magnitude, it may be necessary to separate the two signals by more than one channel. Some radio sets may require frequency separation of more than one channel.

g. Re-use of the same frequency at other locations depends on the transmission properties of the frequency band in question. Some channels or channel groups in the HF band are set aside for long-distance, high-powered clear channels, and others are re-used at more frequent geographic spacing for low-powered, short-distance transmission.

h. For duplex operation provision should be made for wide frequency separation between any transmitting frequency and any receiving frequency at the same site. However, widely separated frequencies are not always available.

i. Frequencies should be selected so that the frequency difference between any pair of frequencies is unlike the difference between any other pair. In some cases, the specific operating frequencies can be chosen so that no third-order product frequency coincides with a receiving channel frequency at the same or a nearby site. Frequencies selected in this manner may result in a setup that is inflexible.

j. Sets of channels that can be used without third-order intermodulation difficulties are listed in table 4-2. It is assumed in the table that the frequency spacing between consecutively numbered channels is a constant; therefore, the difference between channels 1 and 2 is the same as the difference between channels 2 and 3, etc. This table is applicable throughout the spectrum, if the frequency spacing between channels is kept constant during the selection of frequencies at any one installation. In the use of this table, any single constant can be added to all channels in a given set; therefore, if three channels are wanted, these may be 1, 2, and 4, or 71, 72, and 74; 1, 5, and 7, or 31, 35, and 37; etc.

k. Often it is unnecessary to crowd the channels together. Crowding increases the likelihood of interference through the lack of selectivity in the radio equipment or because of spurious output and response. Channel assignments spaced farther apart and not having third-order interference can be obtained in either of two ways. First, a set of channels can be chosen from a larger set in table 4-2. For example, if six channels are wanted, they could be chosen from the set that has ten channels. One such selection might be channels 1, 12, 27, 40, 48, and 62. Second, the table can be modified by multiplying the channel differences by any whole number.

l. The channel selection groups in table 4-2 can be used to select frequencies for duplex operation by taking two equal subgroups from any one set in the table. In addition to the sets of frequencies given in the table, other sets exist that are free from third-order interference.

Table 4-2. Sets Of Channels Having No Third-Order Interference

Number of channel assignments*	Channel numbers
3	1,2,4,
4	1, 2, 5, 7
5	1, 2, 5, 10, 12
6	1, 2, 5, 11, 13, 18,
7	1, 2, 5, 11, 19, 24, 26
8	1, 2, 5, 10, 16, 23, 33, 35
8b	1, 2, 8, 12, 27, 50, 78, 137
9	1, 2, 5, 14, 25, 31, 39, 41, 46
10	1, 2, 8, 12, 27, 40, 48, 57, 60, 62
11	1, 2, 5, 11, 23, 39, 59, 70, 78, 83, 85
12	1, 2, 5, 11, 23, 39, 64, 84, 95, 103, 108, 110
13	1, 2, 5, 11, 23, 39, 53, 80, 100, 111, 119, 124, 126
14	1, 2, 5, 11, 23, 39, 53, 88, 115, 135, 146, 154, 159, 161
15	1, 2, 5, 11, 23, 39, 53, 88, 120, 147, 167, 178, 186, 191, 193
16	1, 2, 5, 11, 23, 39, 53, 88, 117, 149, 176, 190, 207, 215, 220, 222
17	1, 2, 5, 11, 23, 39, 53, 88, 117, 157, 189, 216, 236, 247, 255, 260 262
18	1, 2, 5, 11, 23, 39, 53, 88, 117, 162, 202, 234, 261, 281, 292, 300 305, 307
19	1, 2, 5, 11, 23, 39, 53, 88, 117, 162, 217, 253, 293, 325, 372, 383 391, 396, 398
21	1, 2, 5, 11, 23, 39, 53, 88, 117, 162, 224, 279, 315, 355, 387, 414 434, 445, 453, 458, 460
22	1, 2, 5, 11, 23, 39, 53, 88, 117, 162, 224, 321, 376, 412, 452, 484, 511, 531, 542, 550, 555, 557
23	1, 2, 5, 11, 23, 39, 53, 88, 117, 162, 224, 304, 401, 456, 492, 532, 564, 591, 611, 622, 630, 635, 637
24	1, 2, 5, 11, 23, 39, 53, 88, 117, 162, 224, 304, 361, 458, 513, 549, 589, 621, 648, 668, 679, 687, 692, 694
25	1, 2, 5, 11, 23, 39, 53, 88, 117, 162, 224, 304, 358, 415, 512, 567, 603, 643, 675, 702, 722, 733, 741, 746, 748

* Each set of channels has one pair of adjacent channels: Nos. 1 and 2. To avoid using adjacent channels omit No. 1 or No. 2

b This set has neither third-order nor fifth-order interference.